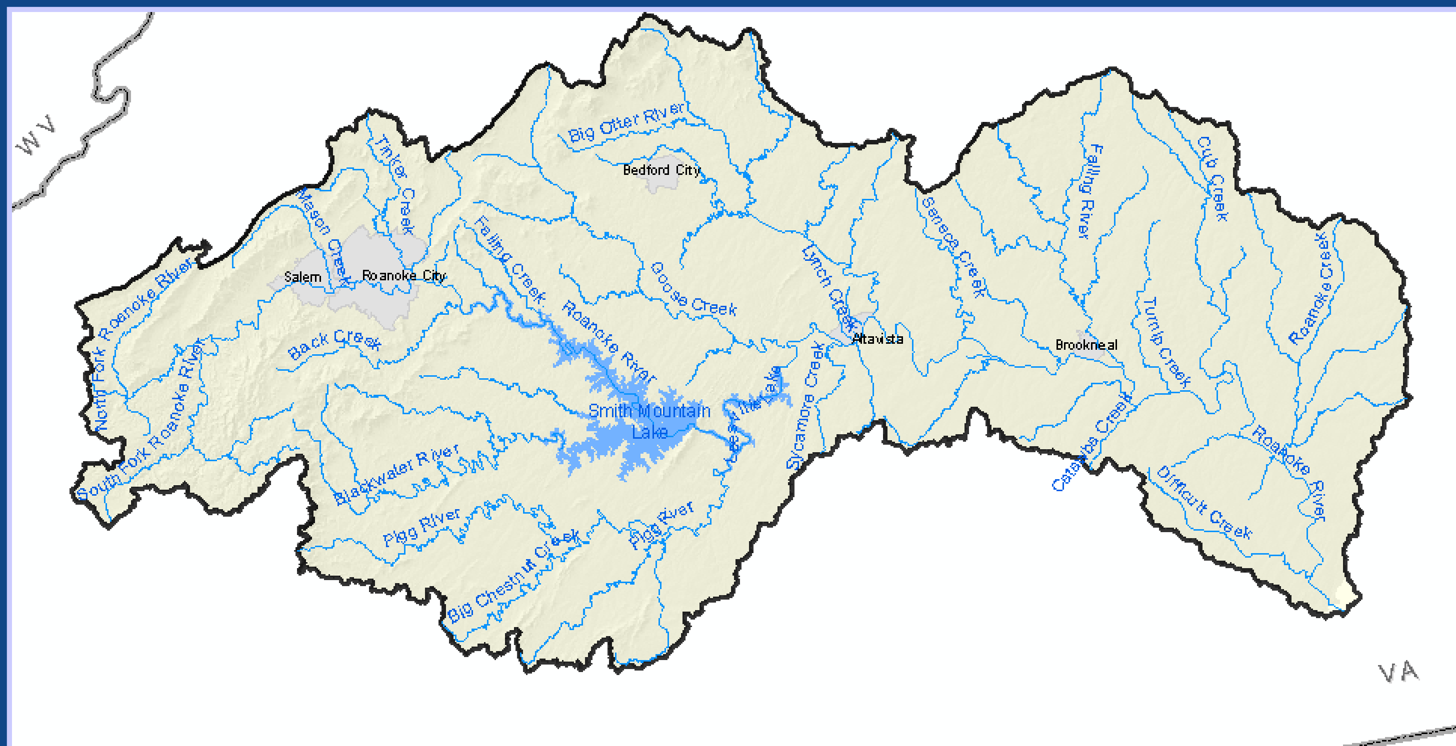
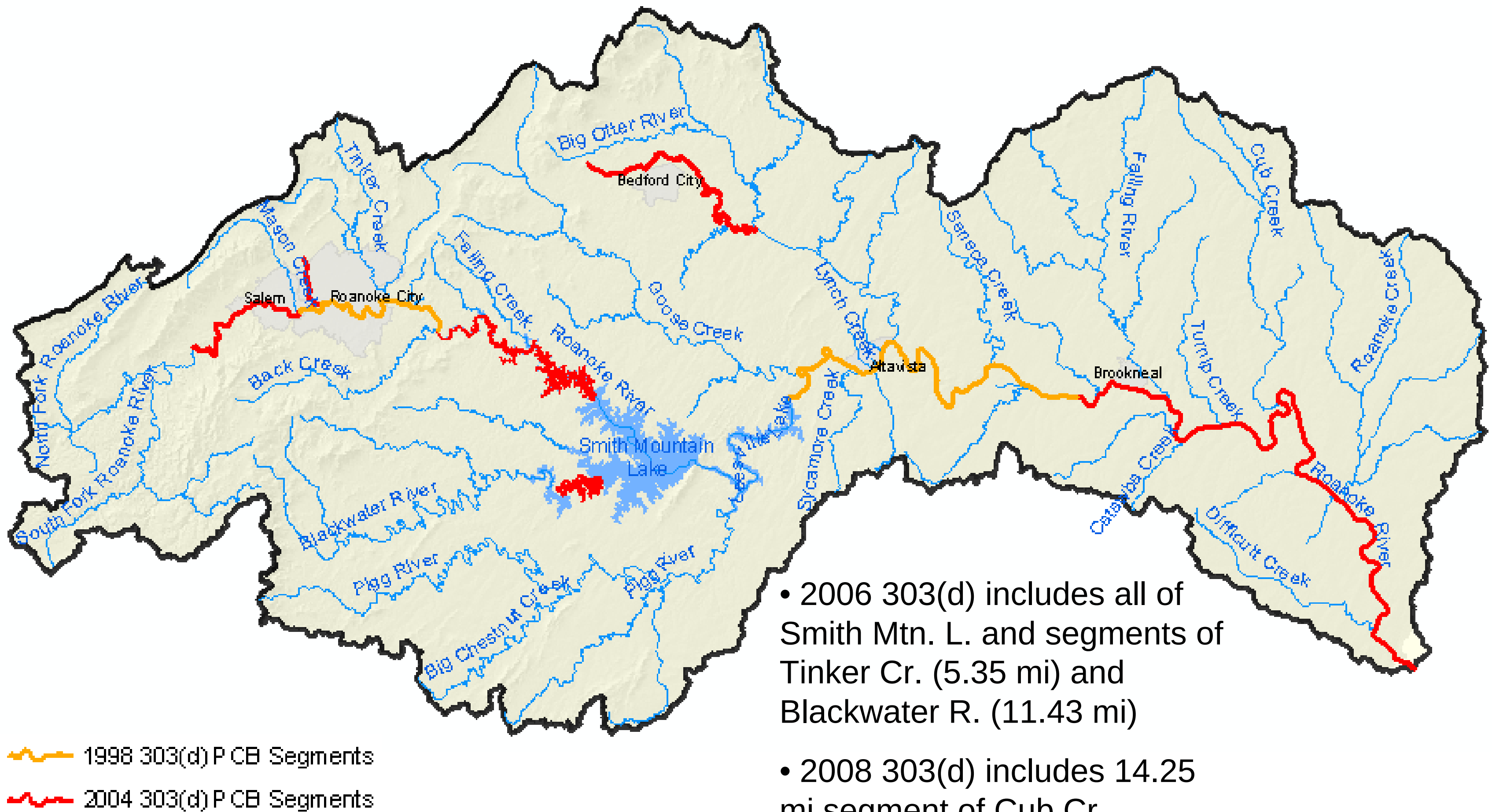
Roanoke River PCB TMDLs

July 29, 2009 TAC meeting



TETRA TECH, INC.

Watershed PCB Impaired Waters



• 2006 303(d) includes all of Smith Mtn. L. and segments of Tinker Cr. (5.35 mi) and Blackwater R. (11.43 mi)

• 2008 303(d) includes 14.25 mi segment of Cub Cr.

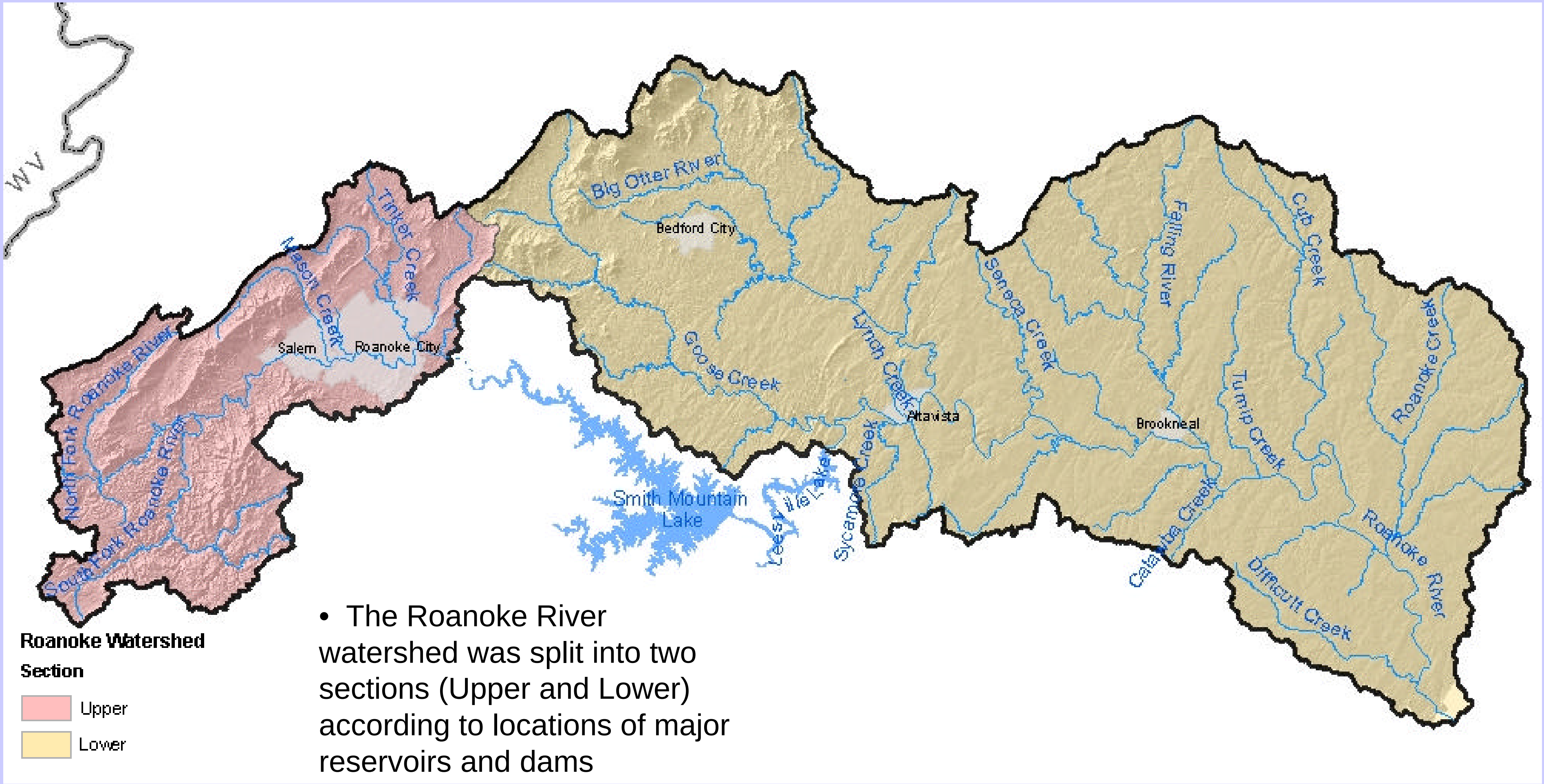
TMDL Model Development

Overview

- LSPC watershed model setup to simulate total PCBs (tPCBs) loading and calculate TMDLs.

- Important components of model setup:
  - <u>Roanoke River watershed sections</u>
    - Upper and lower
    - Subwatershed delineation
    - Boundary condition
  - <u>PCBs representation</u>
    - Total PCBs
  - <u>Model PCB sources</u>
    - Contaminated soils/sites
    - Point sources (effluent, stormwater, MS4)
    - Contaminated river/stream sediments
    - Direct aerial deposition to river/stream segments
  - <u>Develop PCB TMDL endpoint</u>

Watershed Model Sections

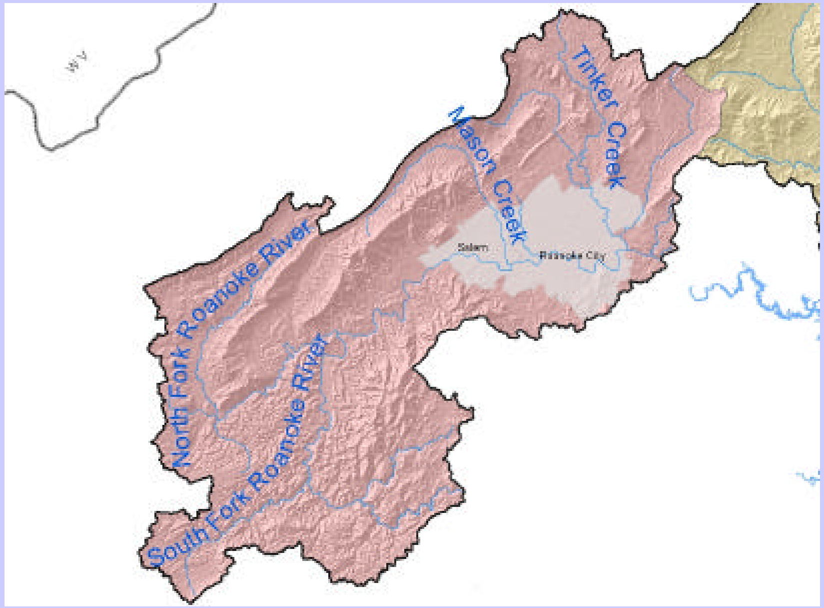


- The Roanoke River watershed was split into two sections (Upper and Lower) according to locations of major reservoirs and dams

Watershed Model Sections

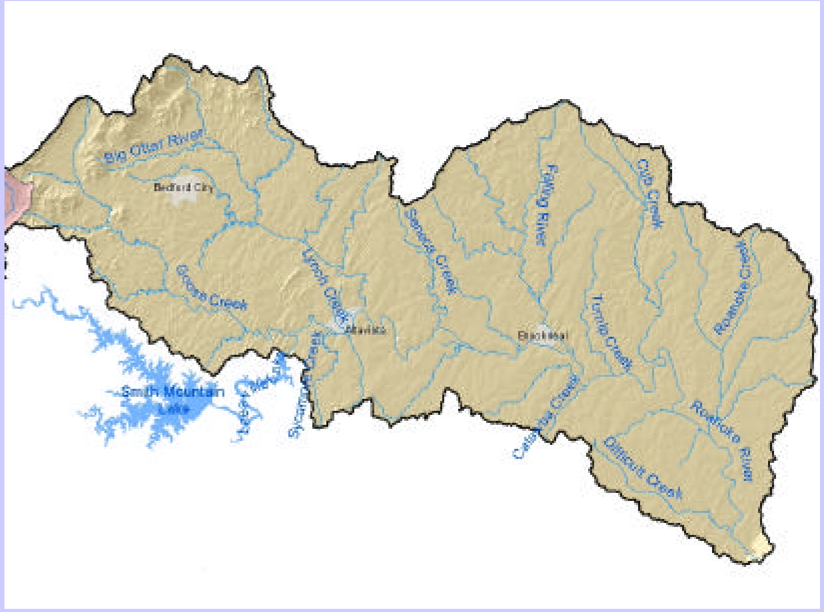
<u>Upper:</u>

- River headwaters in the Blue Ridge Mountains downstream to Niagra Dam ~1.5 miles east of the City of Roanoke



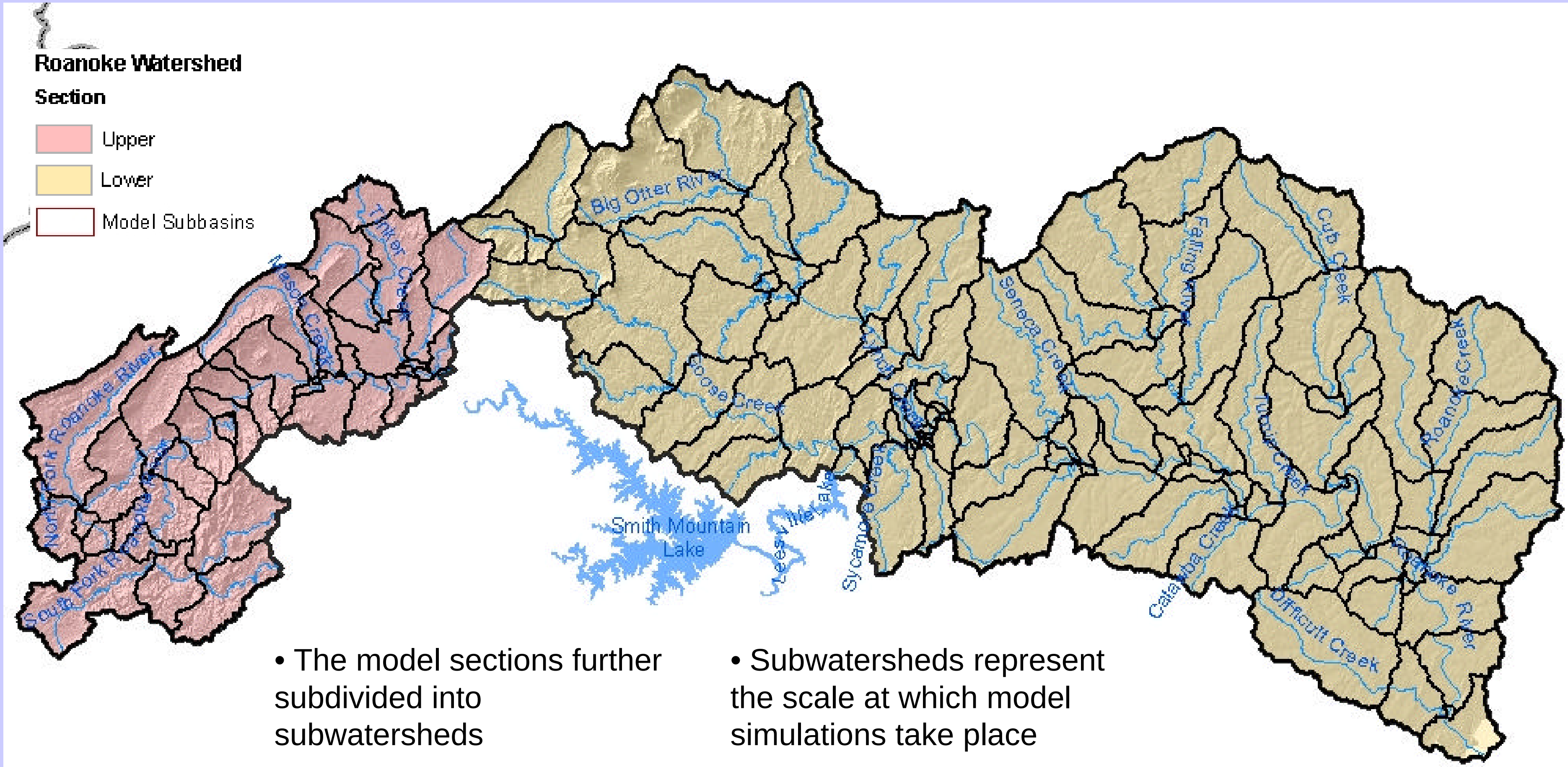
<u>Lower:</u>

- Leesville Dam downstream to confluence with the Dan River at ~river mile 46



➤ Together sections include portions of 1998 303(d) impaired segments

Watershed Model Sections
Subwatershed delineation



- The model sections further subdivided into subwatersheds
- Subwatersheds represent the scale at which model simulations take place

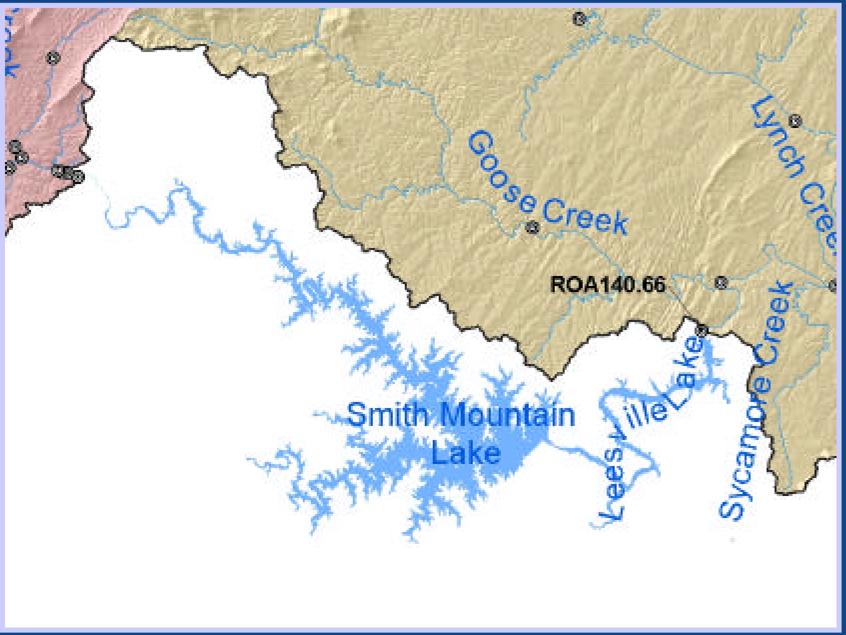
Watershed Model Sections
Boundary Condition

TMDL model does *not* include **Middle** Roanoke section:

- Drainage area of Roanoke R. mainstem from Niagra Dam downstream to Leesville Dam

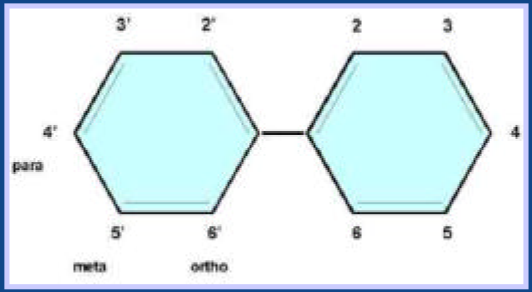
Upper and Lower sections linked using Leesville Dam discharge data and tPCBs fish tissue data:

- Fish tissue data (station ROA140.66) converted to water concentrations
- Flow and water concentration data used to create flow and tPCB load time series (Boundary Condition)



PCB Representation
Overview

- PCBs are a group of chemical species with same basic chemical structure—two bonded phenyl rings substituted with chlorine



- PCBs are grouped according to the degree of chlorination
  - maximum of 10 chlorine atoms can be present on a PCB molecule
  - 10 PCB groups or homologs corresponding to the # of chlorines
- Behavior of PCBs in water with organic components (sediment) affected by degree of chlorination (homolog group)
- Watershed model represents PCBs as both dissolved and sediment associated

PCB Representation
Total PCBs (tPCBs)

- Watershed Model simulates tPCBs (sum of all homologs)
- To capture differences in PCB homolog behavior in water with sediment, components of the watershed model are assigned a representative PCB homolog (weighted average) based on monitoring data grouped at a specific scale
- Key model components within subwatershed framework
  - River/stream water column
  - Streambed sediment
- Model parameters assigned based on representative PCB homolog group
  - tPCBs within key model component behave according to the characteristics of the representative PCB homolog group

Model PCB Sources

Model tPCBs sources include:

- Contaminated upland soils/sites

- Point sources

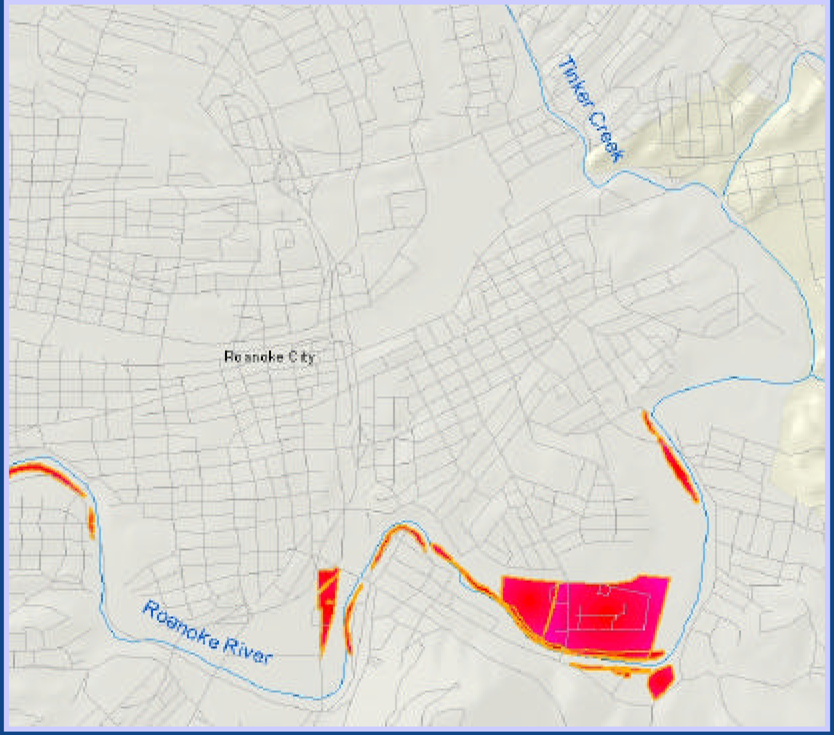
- Contaminated sediments

- Aerial deposition

Model PCB Sources
Contaminated upland soils

Contaminated upland soils:

- Includes sites identified by VADEQ and urban background/unidentified contaminated sites
- Identified site areas estimated from available GIS data and used to create PCB category land uses
- Soil PCB concentrations estimated from available monitoring data
- PCB loads are sediment associated and transported to streams during modeled soil erosion events (storms)

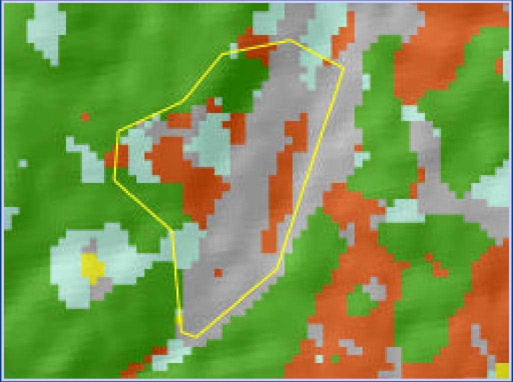


*Example of known contaminated soil areas in City of Roanoke (red)

Model PCB Sources
Point Sources

Point sources include:

- VPDES dischargers—Outfalls monitored as part of VADEQ PCB special study
  - tPCBs loads calculated from monitoring results concentrations and discharge monitoring report (DMR) flows
- General/Stormwater Industrial Permits
- MS4s
  - Modeled land uses were overlain with GIS coverages of MS4s and sites covered by general stormwater permits. PCB loads for the permitted areas were calculated as the load generated by their land areas.



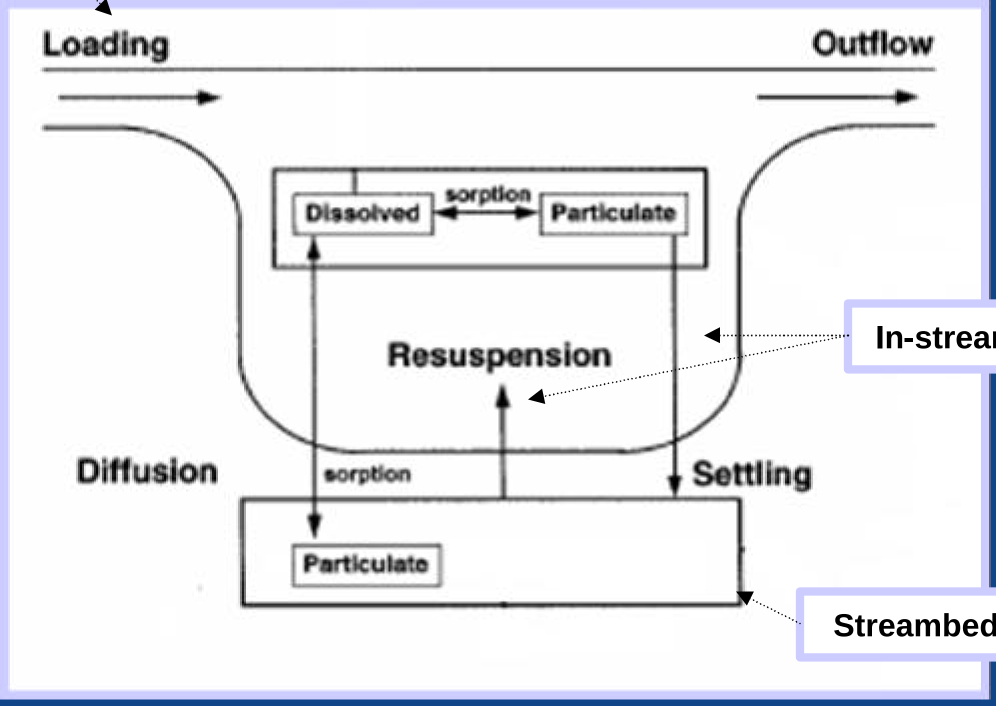
Model PCB Sources
Other Sources

- Contaminated river/stream sediments
  - Sediment PCB concentrations assigned at the subwatershed scale based on available monitoring data
- Direct aerial deposition to river/stream segments
  - The Chesapeake Bay Program Regional PCB atmospheric deposition rate was applied to the entire watershed (1.6 µg/m^2/yr)

PCB Representation

Model Fate Processes

- **Point Sources**
- **Contaminated soils**
- **Upstream contaminated sediment**
- **Aerial deposition**



In-stream hydraulics

Streambed sediments

Chapra, 2007

Watershed BAF
Overview

- A Bio-Accumulation Factor (BAF) defines the susceptibility of an organism to accumulate and maintain pollutant concentrations in tissues
- When developed for fish, BAFs represent the ratio of a pollutant concentration in fish tissue to the pollutant concentration in the surrounding water
  - > the BAF, > tendency to accumulate and retain pollutant
  - A species BAF can be used as multiplier to convert fish tissue concentration to water column concentration

Watershed BAF
TMDL Endpoints

- BAFs for fish species were calculated separately for the upper and lower Roanoke River watershed sections
  - Smith Mtn. Lake and Leesville dams act as a barrier between the two
  - Total PCB homolog composition between the two varies
- Monitoring data used for BAF calculations included:
  - 2007–2008 special study water quality monitoring data
  - 2006 fish tissue monitoring data
- Based on # of sample points and BAF magnitude, carp was selected as the critical BAF species for the upper section
- The VADEQ fish tissue screening level for tPCBs (54 ppb) was converted into TMDL endpoint for the upper (390 pg/L) using target species BAF

TMDL Allocation Development
Overview

- A TMDL is the total amount of pollutant that can be assimilated by the receiving waterbody while still achieving the water quality target (390 pg/L for Upper Roanoke)

- TMDL composed of:
  - Wasteload allocations (WLAs) for point sources
  - Load allocations (LAs) for both nonpoint sources and background levels
  - Margin of safety (MOS) to account for uncertainty in relationship between pollutant loads and water quality

$$\mathrm{TMDL} = \Sigma WLAs + \Sigma LAs + MOS$$

- LSPC model simulations used to calculate tPCBs loading for Baseline (existing) and TMDL scenarios

- Explicit 5% MOS for TMDL

TMDL Allocation Development

Allocation Strategy

- Sources were reduced to meet the TMDL endpoints in the worst case scenario subwatersheds
- Source reductions started with the controllable sources (point sources, contaminated soils) followed by legacy sources (stream sediments and atmospheric deposition)
- VPDES discharger allocations calculated as: facility design flow x water column target

Average annual tPCBs TMDLs for Upper Roanoke River source categories

(-) % reduction indicates Design Flow>Existing Flow

Source Category	Baseline (mg/yr)	TMDL (mg/yr)	% Reduction
VPDES Dischargers	17,665.8	29,754.8	-68.4
Individual Industrial/General Permits	6,773.5	5.1	99.9
MS4	109,676.3	350.7	99.7
Contaminated Sites	7,853.5	1.1	100.0
Urban background	12,082.4	120.4	99.0
Atmospheric Deposition	8,862.5	8,862.5	0.0
Total	**162,914.1**	**39,094.5**	**76.0**

Average annual tPCBs TMDLs for Upper Roanoke River watershed streams

Stream	2008 303(d) list ID	Baseline (mg/yr)	WLA (mg/yr)	LA (mg/yr)	MOS (mg/yr)	TMDL (mg/yr)	% Reduction
North Fork Roanoke River	Not listed	4,923.2	28.2	630.3	34.7	693.2	85.9
South Fork Roanoke River	Not listed	3,532.2	230.2	788.6	53.6	1,072.5	69.6
Masons Creek	Not listed	1,777.5	9.1	193.2	10.6	212.9	88.0
Peters Creek	L12L-01-PCB	1,742.6	65.4	31.2	5.1	101.7	94.2
Tinker Creek	L12L-01-PCB	16,593.6	103.9	3,414.2	185.2	3,703.2	77.7
Wolf Creek	Not listed	1,078.4	10.0	20.3	1.6	31.9	97.0
Unnamed Trib to Roanoke River	Not listed	59.4	0.5	1.3	0.1	1.9	96.8
Roanoke River	L12L-01-PCB	133,207.2	28,157.7	3,455.7	1,663.9	33,277.3	75.0
Upper Total		**162,914.1**	**28,605.0**	**8,534.8**	**1,954.7**	**39,094.5**	**76.0**

Questions?

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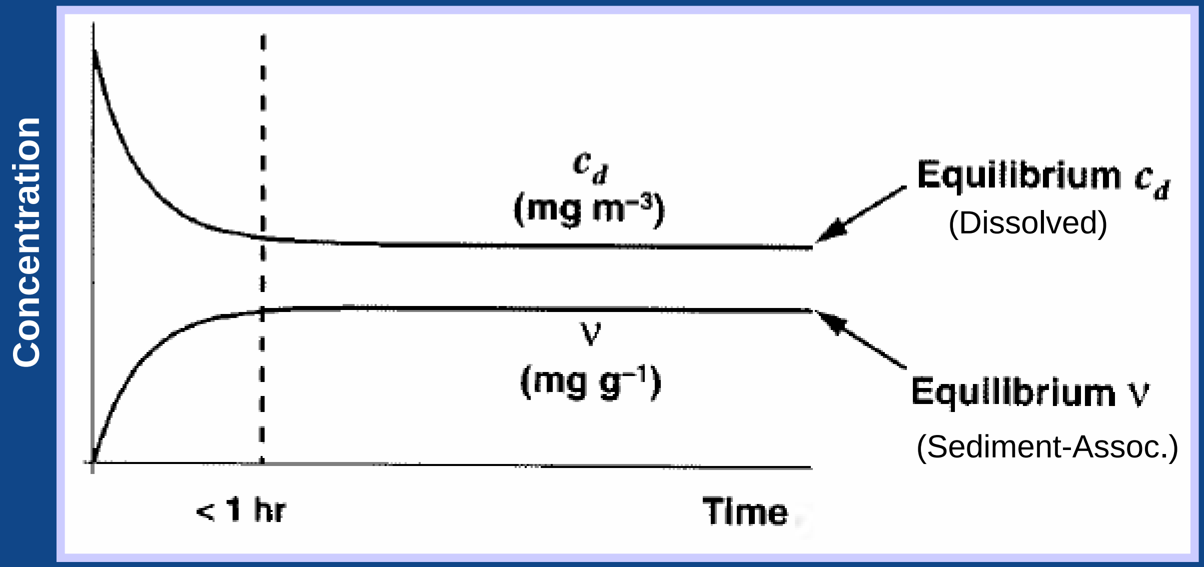
PCB Representation
Dissolved vs. Sediment-Associated

- The chemical behavior dependant on PCB homolog that is relevant to the PCB model is in-stream adsorption and desorption
- Adsorption-desorption describes how PCBs equilibrate/partition between sediment-associated and dissolved states
- All things being equal, > TSS concentration, > PCB sediment-association



Chapra, 2007

PCB Representation
Parameterization

- Two model parameters control the adsorption-desorption process:
  1. Partition coefficient (K_d): the ratio of the chemical sediment-associated concentration to dissolved concentration at equilibrium
  2. Transfer rate (KJT): the rate at which equilibrium is reached

- The greater the K_d value the greater the tendency to be sediment-associated
  - K_d increases with increased PCB chlorination (higher homologs)

- The greater the KJT value the faster equilibrium is achieved
  - KJT decrease with increased PCB chlorination

- The representative homolog assigned to the watershed model components was used to parameterize K_d and KJT at the assigned scale
  - Stream segments
    - Scale: Roanoke River model sections (upper and lower)
  - Streambed sediments
    - Scale: Roanoke River model subwatersheds